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DECISION MAKING IN AGRICULTURE BASED ON LAND SUITABILITY – SPATIAL DATA ANALYSIS APPROACH

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ABSTRACT

India, being an agricultural country analysis of soil texture and water resource plays a vital role in increasing the productivity of crops. The area of study is Vellore district in Tamil Nadu where agriculture is the main occupation. Though it is a fact, most of the land remains uncultivated due to the lack of knowledge of soil and water wealth. This paper proposes a method to analyze the suitability of land based on soil and water resource and predicts the yeild. Initially we apply Analytical Hierarchical Process to evaluate the influence of these factors on productivity. Weighted Overlay Analysis is then used for deriving at the productivity map by imposing the soil and water resource map over the base map. The resultant map is used to mine interesting patterns which gives us potential results in the form of rules that has a high societal impact. The Agricultural administrative authorities can take a decision and help people in converting a barren land into a fertile land thereby increasing the productivity.

Keywords: *Weighted Overlay Analysis, Analytical Hierarchy Process, Association Rule, Decision Making, Land Suitability*

1. INTRODUCTION

India is [6] predominantly agriculture based country with more than two thirds of its population living in rural areas where agriculture is the main occupation of people. Due to the large spatial variation[6] of agriculture field environment (e.g. soil, climate, terrain, etc.), spatial data plays a very important role in identifying the issues critical for crop growth management. Agricultural operation[5] is closely connected with the natural resources that have an obvious spatial character which is considered as an essential character of Geographic Information Systems (GIS). Thus spatial data has an important function to play in agriculture production, especially in field irrigation and soil texture application.

The study area is Vellore District a small city in Tamil Nadu, India that has a lowest percentage of irrigated land in Tamil Nadu. New strategies of agricultural development in this district have to be designed to increase the percentage of irrigated land. Policy makers need to make proper decision to build new irrigation systems based on the Land suitability [7]. Land suitability evaluation defines suitability of certain kinds of land use based on natural and socioeconomic attributes. It is the fundamental work [4] and an important content of overall landuse planning, which requires a scientific approach to guide development, avoid errors in decision-making and over-investment, for sustainable utilization of land resources. This information represents spatial information, which is easily represented [14] and analyzed using GIS.

GIS is a technology used to collect, store, query and analyze spatial information, that combines graphics with different types of database. GIS can also exhibit accurate and real spatial information with charts and texts according to actual need, and can integrate geographic [2] locations and correlate the data attributes**.**

In this paper, two agricultural factors soil and water resource are considered to find the suitable land for irrigation. Pairwise Comparison is performed on these factors by Analytical Hierarchy Process(AHP) to determine the weights. Using these weights Weighted Overlay Analysis(WOA) is performed on land use, soil and water resource thematic maps to find the final land suitability map. Association rule mining is applied on the productivity map and also on the data collected

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from the experts. Rules generated from these data are compared for their accuracy. Policy decisions to increase productivity are taken applying these rules.

Making decisions based on geography is basic to human thinking. [1]Understanding geography and people's relationship to location, informed decisions are taken. GIS is a technological tool that comprehends geography and making intelligent decision making.

2. RELATED WORK

Zorica et al. presents the results of combining [7] GIS and Analytic Hierarchy Process (AHP) in evaluating land suitability for irrigation .Criteria considered for land suitability evaluation are topography, soil quality and the distance between the existing and future irrigation networks. Each criterion is linked to its own spatial layer. Criteria were evaluated by experts in macro that enables implementation of AHP in ArcGIS (written by Oswald Marinoni). Macro also calculates the criteria weights and assigns them to the related spatial data. Three weighted spatial layers are then combined into one, final suitability map. As a part of the further analysis, they compared the final suitability map with the map that presents areas where land owners expressed their interest for irrigation.

Multicriteria Evaluation (MCE) methods [8] is used to solve spatial decision problems derived from multiple criteria. By integrating the evaluation techniques with GIS, the influential factor are evaluated and more accurate decision were taken in a short time.

Crop [9] growth and yield are determined by a number of factors such as genetic potential of crop cultivation, soil, weather, cultivation practices (date of sowing, amount of irrigation and fertilizer) and biotic stresses. Recent [3] developments in GIS technology allow capture, storage, retrieval, visualization and modeling of geographically linked data. Crop simulation model are designed using the Remote sensing data and GIS.

Cellular Automata(CA) [4] is used in simulation of various spatial application. CA express complex systems which are difficult to perform only with mathematical formula. In combination with GIS Software, such as ArcGIS, it can directly and vividly reflect the geospatial state changes and accomplish many kinds of spatial analysis. This paper presents CA based GIS approach for simulation of land suitability evaluation. A suitability simulation result map is generated and evaluated.

3. METHODOLOGY

Secondary Agricultural data for Vellore District is taken as an input dataset. The objective is to analyse land suitability to predict crop productivity. The methodology used for our analysis is depicted in Figure 1.The toposheets of the thematic maps are scanned and the images are stored as jpeg files. The Raster images are then converted into vector images which is geoprocessed and digitized .Spatial data functions like point reference,setting spatial attributes is used to transform the spatial file into GIS format. Edge matching is a technique used to adjust the position of features across the boundaries of the map.

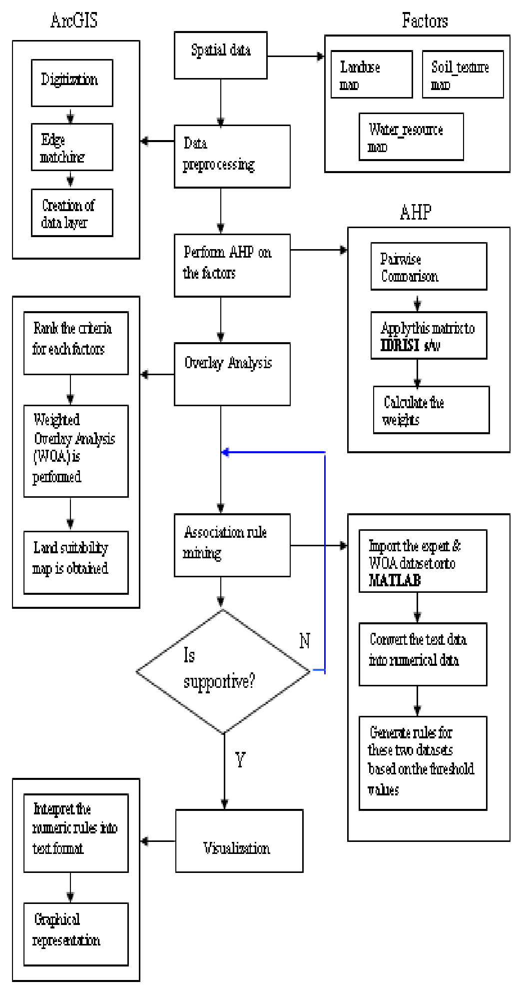

Fig. 1. Methodology Work flow.

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3.1. *Analytical Hierarchy Process*

AHP is used to determine the degree to which soil and water influences the analysis. AHP [1] is a framework that allows to decompose the problem in a hierarchical structure to make complex problems simpler that helps a lay man to take decision. In AHP Pairwise Comparison [12] is used to find the relative importance between each criteria as shown in Table 1.

Table 1. Pairwise Comparison Matrix

	Water	Soil	Priority
Water	1	7	0.3
Soil	1/7	1	0.7

Sum of priorities = 1

Table 2. Pairwise Rating Scale

1/9	1/7	1/5	1/3	1	3	5	7	9

Less Important More Important

Pairwise comparison is performed based on the rating scale shown in Table 2. Two factors are compared using the rating scale which ranges from 1 to 9 with respect to their relative importance . This parameter is computed against each pair based on the opinion of experts. IDRISI software is used to process the input where the priority of each factor is calculated using the eigen vectors. The Weights calculated using AHP is shown in Table 3.

Table 3. Weights calculated using AHP

SNO	Factor	Eigen Vector	Weights Assigned
1	Rivers	0.30	30%
2	Soil	0.70	70%

3.2. *Weighted Overlay Analysis*

Weighted overlay is a technique[10] for applying a common scale of values to diverse and dissimilar input to create an integrated analysis. ArcGIS is used to implement Weighted Overlay Analysis (WOA). The weights calculated for each factor using AHP are applied in the influence column of WOA as shown in Fig 2.

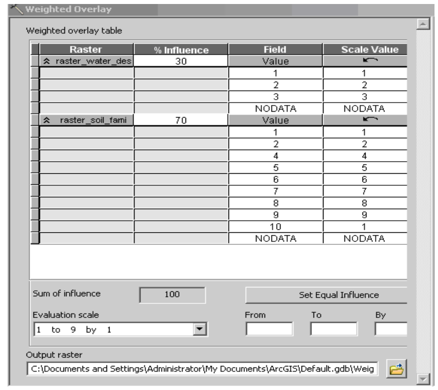

Fig 2. Weighted Overlay Analysis

The WOA window (Fig 2) consists of the following properties

- Raster - The raster data of the two factors (soil,water) are given in this
- Influence - The influence percentage for soil and water are 70% and 30%.
- Field - The field value of the criteria for each factor is given in this column.
  NODATA- It assigns no data to the output cells when the input raster data have a different value set for that cell.
- Scale - The criteria for each factor are ranked using experts opinion. Table 4,Table 5,Table 6 shows the criteria value and their ranks for soil texture, water resource and productivity factors.

CRITERIA	RATINGS
Coarse Loamy	2
Clayey	1
Clayey Skeled	5
Loamy Skeled	4
Fine Loamy	3
Fine	6
Loamy	7
Contrasting Particle Size	8

Table 4. Scale value for Soil

CRITERIA	RATING
River	1
Tanks	2

Table 5. Scale value for water resource

CRITERIA	RATING
Poor	1
Low	2
Moderate	3
Good	4
High	5

Table 6. Scale value for Productivity

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The above mentioned properties, are used to perform overlay analysis on the base boundary map (Fig 3), soil texture(Fig 4) and water resource map(Fig 5). As a result the productivity map(Fig 6) is generated that indicates the suitable land for irrigation in Vellore District.

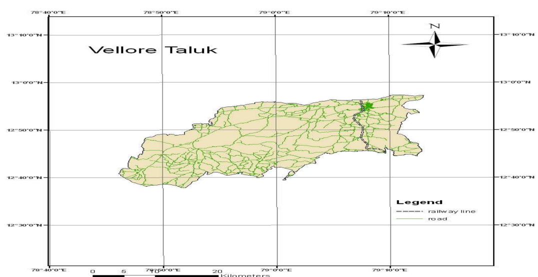

Fig 3. Base Map

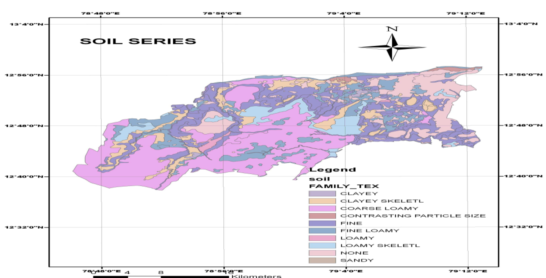

Fig 4. Soil Texture Map

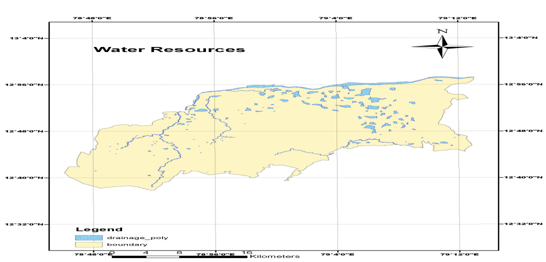

Fig 5. Water Resource Map

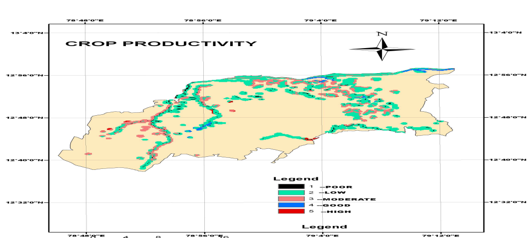

Fig 6. Productivity Map

Land suitability map depicted in Fig 6 shows that the Vellore district mainly consists of barren land .This influence matches with the real data collected from the Agriculture Office.

3.3 *Association Rule Mining*

The Productivity map thus generated is further analyzed to generate association rule for effective decision making. Association rule mining [13] is a way to find interesting patterns among large sets of data items and to generate strong association rules based on the given threshold values. Rules are generated based on the two input factors soil texture and water resource which is taken as an antecedent and productivity of the crop as the consequent. Categorical data is represented in numbers as shown in Table 7,Table 8 and Table 9.

Table 7. Interpretation Of Soil Texture

Sandy	Coaloamy	Clayey	Clayske	Loaske	Finelo	Fine	Loamy	CPS	none
1	2	3	4	5	6	7	8	9	10

Table 8. Interpretation Of Water Resource

River	Tank
11	22

Table 9. Interpretation Of Crop Productivity

Poor	Low	Moderate	Good	High
10	20	30	40	50

The two dataset taken for mining are

(i) The dataset generated in productivity map using weighted overlay analysis is shown in Fig 7.

(ii) The dataset generated using the comments received from experts and farmers is shown in Fig 8.

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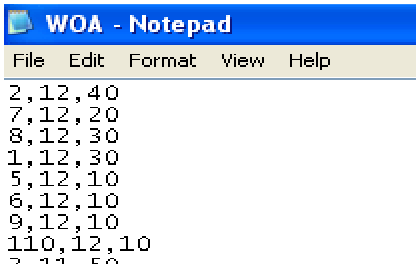

WOA - Notepad
File Edit Format View Help
2,12,40
7,12,20
8,12,30
1,12,30
5,12,10
6,12,10
9,12,10
110,12,10

Fig. 7. Woa Data

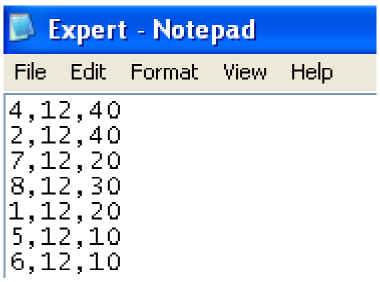

Expert - Notepad
File Edit Format View Help
4,12,40
2,12,40
7,12,20
8,12,30
1,12,20
5,12,10
6,12,10

Fig 8. Expert Data

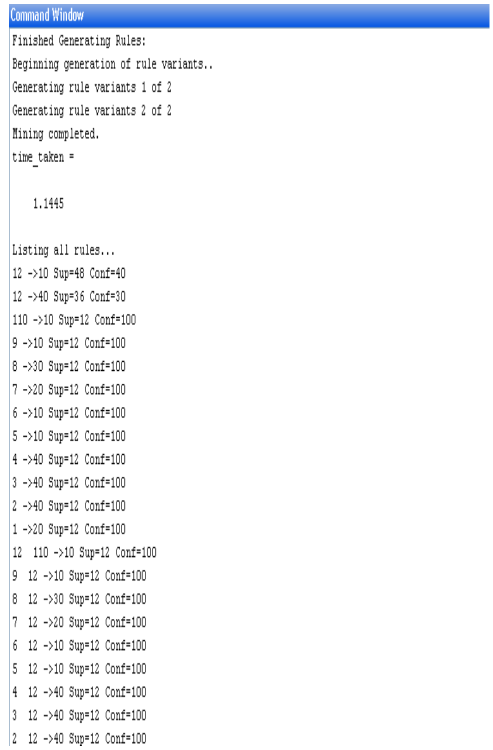
Rules are generated in MATLAB [11] by setting appropriate properties like support and confidence in the criteria window. Rules that satisfy support and confidence threshold values are considered for analysis. The rules generated in numbers are shown in the Fig 9 and Fig 10.


```
Command Window
Generated next set 3 out of 3
Finished Generating Rules:
Beginning generation of rule variants..
Generating rule variants 1 of 2
Generating rule variants 2 of 2
Mining completed.
time_taken =

    0.5714

Listing all rules...
12 ->10 Sup=16 Conf=50
11 ->50 Sup=8 Conf=100
110 ->10 Sup=4 Conf=100
9 ->10 Sup=4 Conf=100
8 ->30 Sup=4 Conf=100
7 ->20 Sup=4 Conf=100
6 ->10 Sup=4 Conf=100
5 ->10 Sup=4 Conf=100
4 ->50 Sup=4 Conf=100
3 ->50 Sup=4 Conf=100
2 ->40 Sup=4 Conf=100
1 ->30 Sup=4 Conf=100
12  110 ->10 Sup=4 Conf=100
9  12 ->10 Sup=4 Conf=100
8  12 ->30 Sup=4 Conf=100
7  12 ->20 Sup=4 Conf=100
6  12 ->10 Sup=4 Conf=100
5  12 ->10 Sup=4 Conf=100
4  11 ->50 Sup=4 Conf=100
3  11 ->50 Sup=4 Conf=100
2  12 ->40 Sup=4 Conf=100
1  12 ->30 Sup=4 Conf=100
Finished listing all rules
```

Fig 9. Rules Generated For WOA Dataset


```
Command Window
Finished Generating Rules:
Beginning generation of rule variants..
Generating rule variants 1 of 2
Generating rule variants 2 of 2
Mining completed.
time_taken =

    1.1445

Listing all rules...
12 ->10 Sup=48 Conf=40
12 ->40 Sup=36 Conf=30
110 ->10 Sup=12 Conf=100
9 ->10 Sup=12 Conf=100
8 ->30 Sup=12 Conf=100
7 ->20 Sup=12 Conf=100
6 ->10 Sup=12 Conf=100
5 ->10 Sup=12 Conf=100
4 ->40 Sup=12 Conf=100
3 ->40 Sup=12 Conf=100
2 ->40 Sup=12 Conf=100
1 ->20 Sup=12 Conf=100
12  110 ->10 Sup=12 Conf=100
9  12 ->10 Sup=12 Conf=100
8  12 ->30 Sup=12 Conf=100
7  12 ->20 Sup=12 Conf=100
6  12 ->10 Sup=12 Conf=100
5  12 ->10 Sup=12 Conf=100
4  12 ->40 Sup=12 Conf=100
3  12 ->40 Sup=12 Conf=100
2  12 ->40 Sup=12 Conf=100
```

Fig 10. Rules Generated For Expert Dataset

Thus the rules generated can be interpreted and depicted as shown in Table 10,

Table 10. Generation Of Rules

Rule Number	Rules Generated in numbers	Interpretation
Rule 1	3 11→50	If soil_texture ='Clayey' and Water_resource='River' Then Productivity='High'
Rule 2	7 12→20	If soil_texture ='Fine' and Water_resource='Tank' Then Productivity='Low'
Rule 3	1 12→30	If soil_texture ='Sandy' and Water_resource='Tank' Then Productivity='Moderate'
Rule 4	9 12→10	If soil_texture ='Contracting Particle size' and Water_resource='Tank' Then Productivity='Poor'
Rule 5	8 12→30	If soil_texture ='Loamy' and Water_resource='Tank' Then Productivity='Moderate'
Rule 7	5 12→10	If soil_texture ='Loamy Skeletl' and Water_resource='Tank' Then Productivity='Poor'
Rule 8	4 11→50	If soil_texture ='Clayey Skeletl' and Water_resource='River' Then Productivity='High'
Rule 9	2 12→40	If soil_texture ='Coarse Loamy' and Water_resource='River' Then Productivity='Good'

4. EXPERIMENTAL RESULTS

Graph is generated for these two datasets with respect to Soil texture in X axis, water resource in Y axis and Productivity in Z axis. Graphical representation of two data set with parameter soil-texture, water resource and productivity are determined using WOA and expert data.

When these two graphs are compared with each other we can decide that the Graph generated using the WOA is 80% accurate with the graph generated using the Experts opinion as shown in Fig 15. So based on the rules and graph generated the farmer or the agriculture district officer can make a proper decision to increase the productivity of the crops.

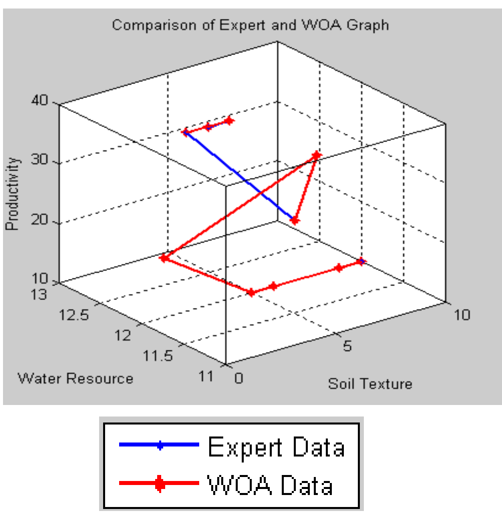


Fig 15 Comparison between Predicted Vs Real Graph

5. CONCLUSION

Even though predicting the land suitability and soil texture is a topic of interest for the past few years no method has clearly indicated the yield accurately. GIS plays a significant role in spatial data analysis and is a major player in this area. Informed knowledge discovery with the recorded data from the agricultural department need to use background knowledge obtained from farmers to help us in generating rules that is hidden in the real life situation. The knowledge discovery process used in our work is three fold. Analytical Hierarchy Process is used to discover the influential factors which in turn are given as an input to Weighted Overlay Analysis. Knowledge discovery in the form of rules are generated from these analyses. Findings indicate that the study made in this work is practically valid.

6. FUTURE WORK

The results thus obtained have proved to be accurate when compared with the yield. This analysis can be extended to consider more parameters as pest management, fertilizer consumption for specific crops that produces more accurate results.

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